

REINHOLD ENVIRONMENTAL Ltd.



2012 NO_x-Combustion Round Table & Expo Presentation

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Modification of the Catalyst to Enhance Performance in Biomass Units

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Presentation Contents



- **About DG Whitefield**
- **The RSCR System**
- **SCR/RSCR Catalyst Regeneration**
- **The Catalyst Regeneration Project:**
Modification of the Catalyst to Enhance Performance in Biomass Units



About DG Whitefield



- **19 MW (zero discharge)**
- **46 acre parcel in New Hampshire**
- **1987 construction start**
- **March 1988 COD**
- **20 year rate order agreement with Public Service of New Hampshire**
- **2004 unit was sold to investor, which wanted to qualify for Renewable Energy Credits (REC)**
- **July 2004 RSCR is being build**
- **Oct 2004 REC is granted**
- **Multi-year power purchase agreement with Constellation Energy**



- **Fuel:**
 - Whole Tree Chips
 - Bark
 - Sawdust
 - 235,000 wet tons of wood waste annually
- **Fuel Regions:**
 - New Hampshire (majority)
 - Vermont, Massachusetts and Maine
- **Ash:**
 - 100% marketed to local farmers for field spreading (provides pH improvement and nutrients for plant growth)



The Typical RSCR System

Regenerative Selective Catalytic Reduction (RSCR™)

A highly-efficient NO_x (nitrogen oxides) control system designed especially for tail-end, low temperature applications.

- **High NO_x removal efficiency**
- **Achieves high heat recovery > 95%**
 - Minimizes energy costs
 - Minimizes energy costs
 - Flexible fuel source for burners
- **Emissions guarantees**
 - NO_x removal, NH₃ slip, catalyst life
- **Proprietary NH₃ system design**
 - Static mixers ensure high performance and low slip
 - Aqueous or anhydrous NH₃ designs available
- **Self-contained, tail-end unit**
 - Includes fans, controls, burners



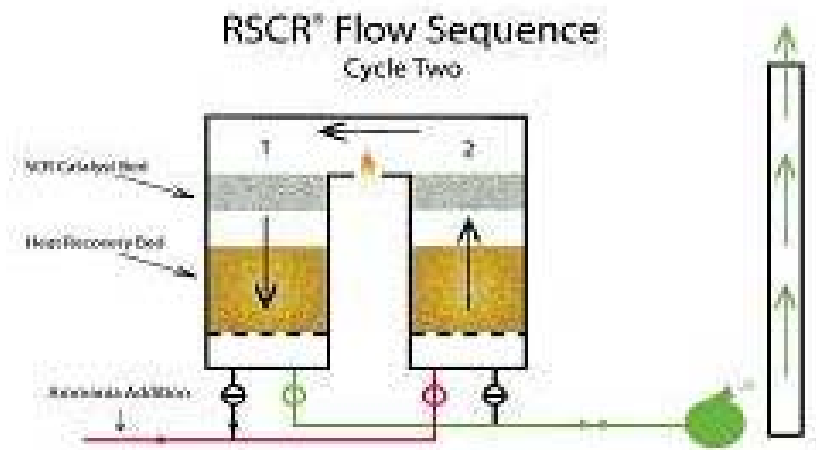
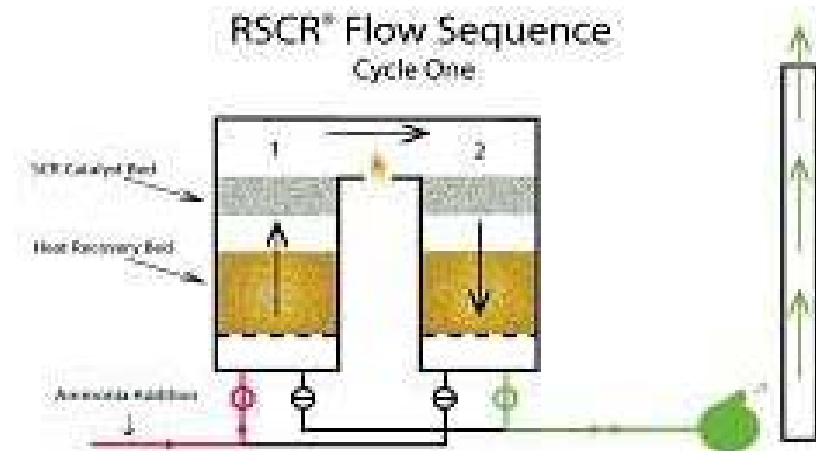
- **Modular, standard design to minimize installation time and cost**
- **Bypass capabilities included**
- **CO reduction catalyst (optional)**

How the Typical RSCR Works

- **Flue Gas directed to the inlet of the RSCR**
 - Mixes with ammonia

- **Cycling beds of ceramic media**
 - Heat transfer media beds
 - Retains heat of 500 degrees F

- **Catalyst modules**
 - Ammonia reacts with NOx to form nitrogen and water
 - NOx removed



SCR / RSCR Catalyst Regeneration Nomenclature

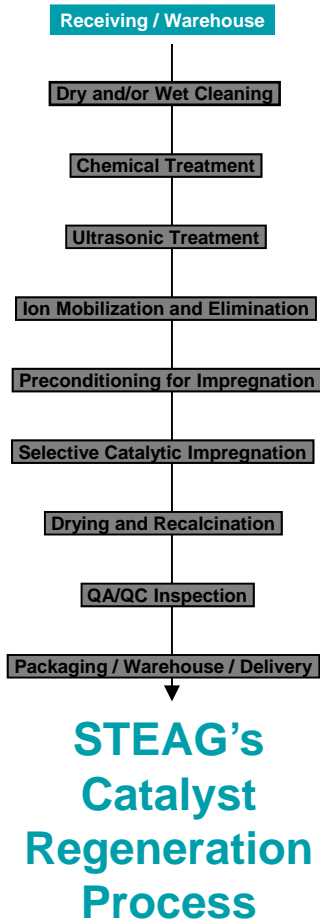


- **Cleaning**
 - The removal of physical restrictions, such as blinding layers and large particle ash (LPA).
- **Rejuvenation**
 - The removal of catalyst poisons without the need for replenishing catalytically active compounds.
- **Regeneration**
 - The removal of catalyst poisons plus restoration of catalytic activity by the addition of catalytically active ingredients.



SCR / RSCR Catalyst Regeneration

STEAG's Regeneration Process Steps



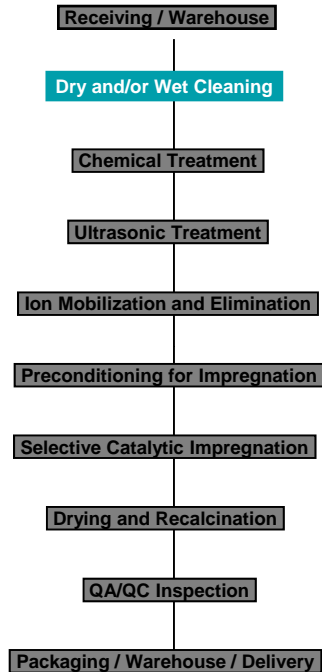
Receiving and warehousing:

- STEAG has capabilities of receiving by flatbed, covered trailer or sea container.
- Modules are individual stenciled with an identifying number for tracking and Q/A through the process.
- Modules are inspected for damage during removal or transport.

Catalyst Regeneration



STEAG's Regeneration Process Steps



**STEAG's
Catalyst
Regeneration
Process**



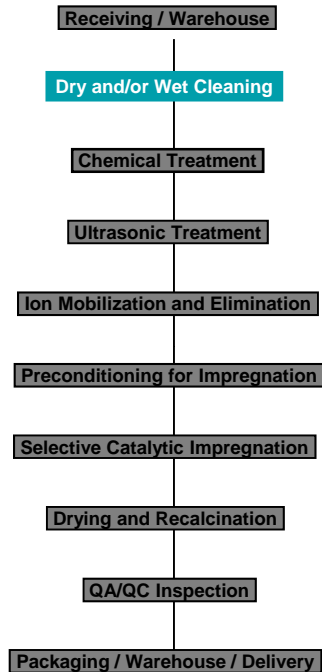
Dry mechanical and/or wet cleaning for fly ash removal:

- Modules can hold up to 2,500 lbs. of fly ash.
- Preliminary cleaning only as needed to remove LPA and fly ash.
- In case of plate type catalyst dry cleaning is used by disassembling the plate boxes to remove fly ash and/or LPA trapped between plates.
- Inspection of the module (damage, erosion, etc.).

Catalyst Regeneration



STEAG's Regeneration Process Steps



**STEAG's
Catalyst
Regeneration
Process**

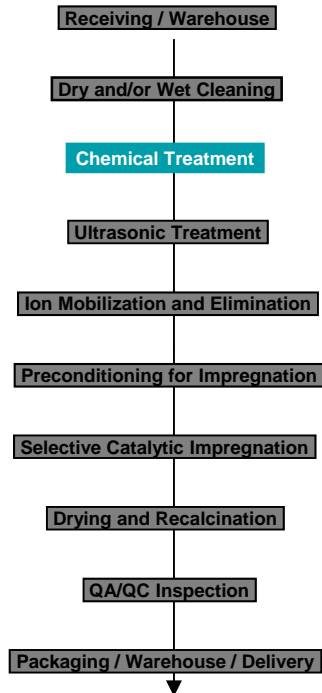


Wet Pre-cleaning stage:

- In case of honeycomb and/or corrugated catalyst wet cleaning with water is used to remove additional fly ash / LPA particles.
- Modules are thoroughly inspected for damage during the completion of wet cleaning.
- The wet cleaning water is recycled (similar to a car wash) to minimize water consumption of the process. Solids are removed through a sedimentation process.

Catalyst Regeneration

STEAG's Regeneration Process Steps



STEAG's Catalyst Regeneration Process

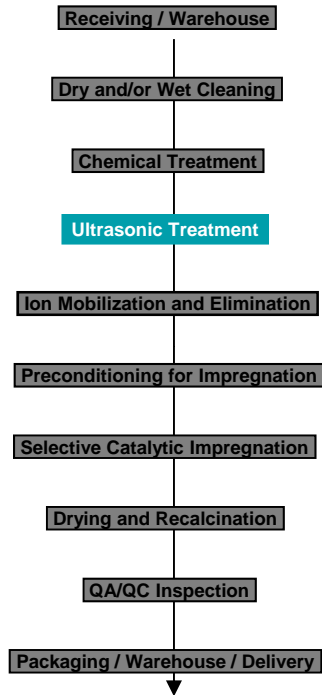


Multi-stage wet chemical treatment for poison removal:

- Complex combinations of treatment time, pH, surfactants, chemical types, concentrations and temperature.
- Very precise process control to maintain stable process conditions including continuous removal of solids and replacement of spent solution.
- Tailored to avoid unwanted activation of metal ions (i.e. $\alpha\text{-Fe}_2\text{O}_3$ to $\gamma\text{-Fe}_2\text{O}_3$) while maximizing their removal.

Catalyst Regeneration

STEAG's Regeneration Process Steps



**STEAG's
Catalyst
Regeneration
Process**

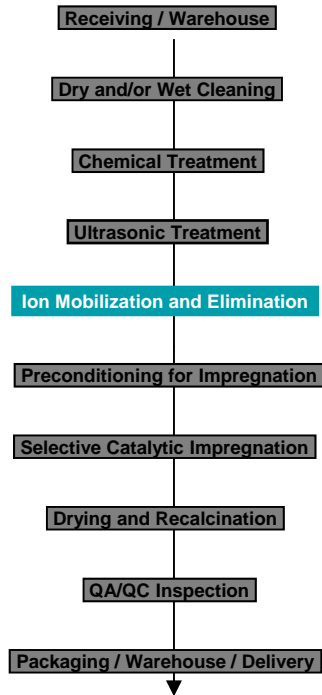


Ultrasonic treatment:

- Time, pH, concentration and temperature controlled solution in the ultrasound.
- Very precise process control to maintain stable process conditions including continuous removal of solids and replacement of spent solution.
- Significant damage can occur to catalyst from ultrasonic energy, therefore ultrasound is only used when really needed.

Catalyst Regeneration

STEAG's Regeneration Process Steps



**STEAG's
Catalyst
Regeneration
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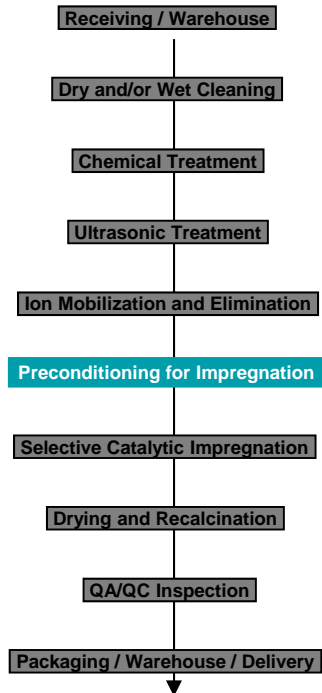


Ion mobilization and elimination:

- More advanced, complex compounds but fewer chemicals used for cation mobilization.
- Highly effective cation elimination, especially of $\gamma\text{-Fe}_2\text{O}_3$ is very critical for achieving a low SO_2/SO_3 conversion rate.
- Critical for preparation for Selective Impregnation[®]

Catalyst Regeneration

STEAG's Regeneration Process Steps



STEAG's Catalyst Regeneration Process

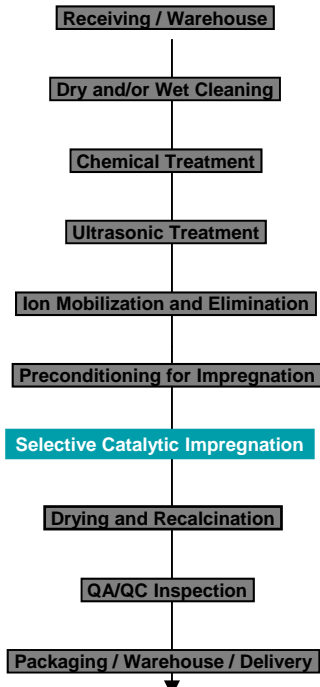


Pre-conditioning for Selective Impregnation[®]:

- Effective removal of all cleaning reagents and residual chemicals from the prior treatment.
- Controlled drying to a defined residual moisture content:
 - Catalyst module can hold up to 500 lbs. of water.
 - Catalyst drying after pre-conditioning / neutralization / rinsing and catalyst critical for correct impregnation.

Catalyst Regeneration

STEAG's Regeneration Process Steps



**STEAG's
Catalyst
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Process**



Selective Impregnation[®] of catalytic activity:

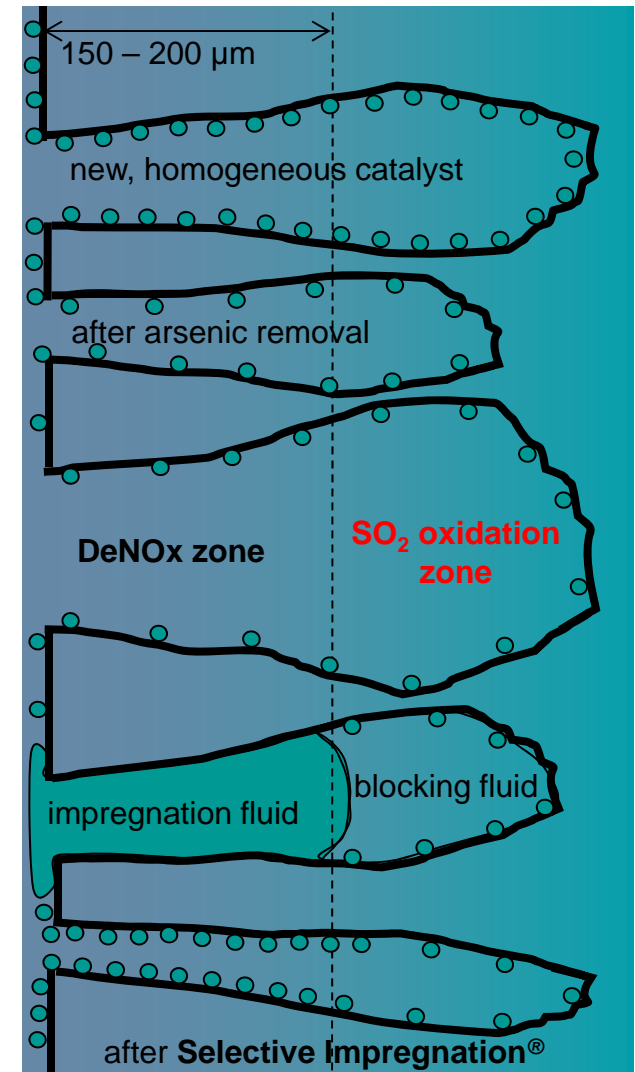
- Patented one-step process for the replenishment of V_2O_5 and WO_3 or V_2O_5 and MoO_3 depending on catalyst type.
- Selective Impregnation[®] – the local distribution of active V_2O_5 on the catalyst surface is extremely critical for the effective reduction of the SO_2/SO_3 conversion rate.

Selective Impregnation®



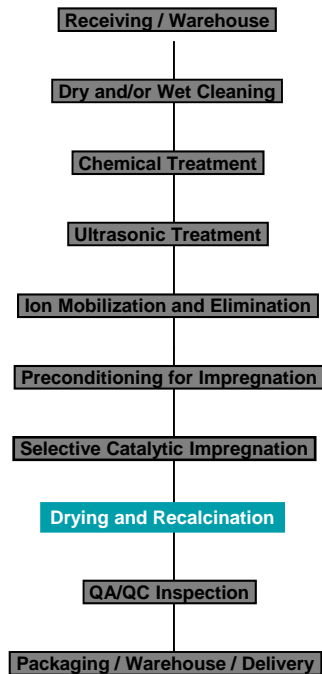
Selective Impregnation® is a patent pending process, which takes full advantage of these effects by:

- Removing an appreciable quantity of catalytically active compounds along with arsenic and other catalyst poisons.
- Selectively impregnating additional catalytically active compounds (Mo, V, W) only in the DeNOx zone.
- Actively preventing impregnation of any catalytically active compounds in the SO₂ oxidation zone by “sealing off” this area by means of a blocking fluid.



Catalyst Regeneration

STEAG's Regeneration Process Steps



STEAG's Catalyst Regeneration Process



Final drying and recalcination:

- Precise high temperature treatment process to regain the mechanical strength (i.e. WO_3 crystallization).
- Activation of ingredients added during impregnation (i.e. vanadium oxalate to V_2O_5).
- Removal of captured crystalline water from crystalline TiO_2 structure.

Catalyst Recalcination Benefit

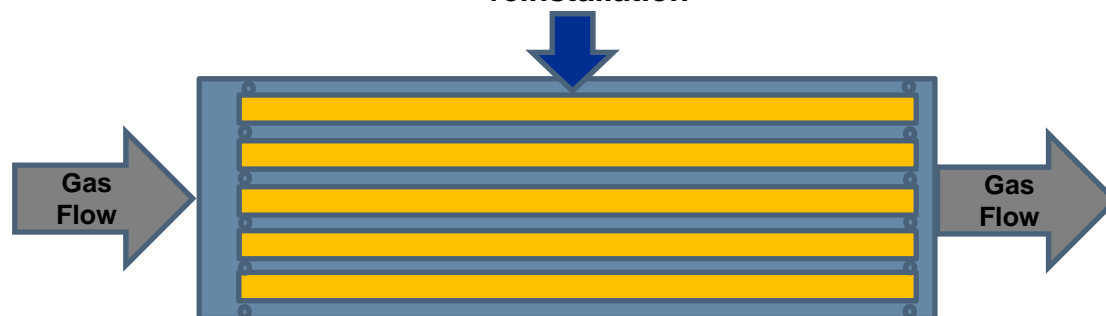


The value of one-step Selective Impregnation[®] and catalyst recalcination:

- When is catalyst at it weakest?
 - After the regeneration process prior to recalcination.
- When is the catalyst at it greatest stress?
 - During the transportation, handling and reinstallation of the catalyst.
 - Catalyst strength needs to be established prior to shipment, handling and reinstallation.

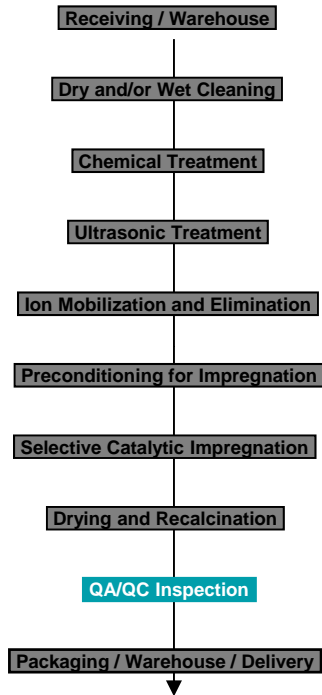


Highest stress area occurs during transport, handling and reinstallation



Catalyst Regeneration

STEAG's Regeneration Process Steps



STEAG's Catalyst Regeneration Process



Quality Assurance / Quality Control:

- Inspection and verification of cleaned channels.
- Bench and micro scale catalyst testing capabilities in Kings Mountain, NC.
- XRF capabilities.

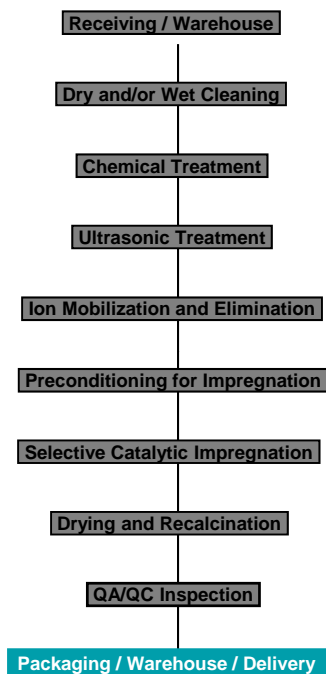
Repair of mechanical damage (only if needed):

- Repair of damaged module casings.
- Consolidation of damaged modules into good modules.
- Repacking of honeycomb catalyst.

Catalyst Regeneration



STEAG's Regeneration Process Steps



**STEAG's
Catalyst
Regeneration
Process**



Warehousing / Shipping / Installation:

- Long term storage capacity of 12,000 modules on site.
- Full service shipping (if desired).
- Full service catalyst removal and installation (if desired).
- Current capacity 40 – 50 modules per day.

Modification of the Catalyst to Enhance Performance in Biomass Units



- **Project Goals**

- Operation of the unit with less catalyst volume, while maintaining the required NOx reduction
- Improvement of the performance of the catalyst to obtain this objective.



Project Description



- **After six (6) years RSCR Catalyst needed replacing**
 - Declining NOx conversion efficiency
 - Increasing ammonia usage
- **New Catalyst vs. Regenerated Catalyst**
- **In November 2010 a catalyst layer was removed**
 - Shipped to STEAG
 - Logistics: Modules Oversized
- **Cleaning and Testing was performed**
- **Dramatic Improvements were seen**
 - At lower gas stream temperature
- **Important: The RSCR unit provides NOx conversion solely at boiler gas temperature, without an auxiliary heat source.**



Project Description



- **Regeneration complete and re-installed in June 2011**
- **Two layers removed only the regenerated layer installed**
 - Operating on 2/3 volume (Goal)
 - One layer of new Catalyst
- **Single layer usage for testing**
- **Regenerated modules perform as well, under all operating conditions, as new**
- **7 months of continuous operations - no degradation in performance.**
- **Annual stack compliance testing for NH Dept of Environmental Services in 2011**
 - **Lowest ammonia slip levels in the facility's history at 1.12 ppm.**



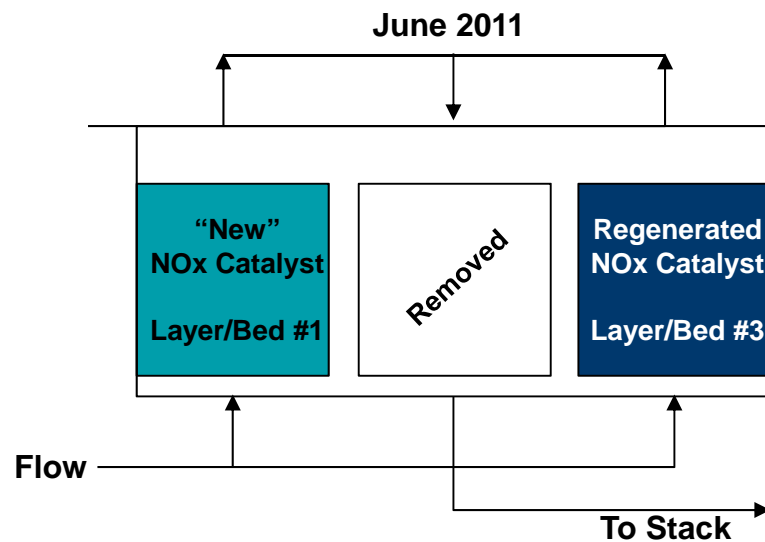
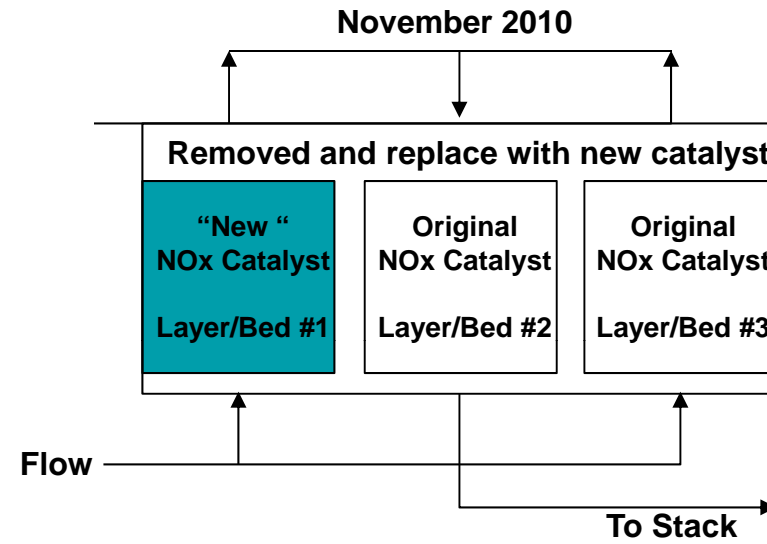
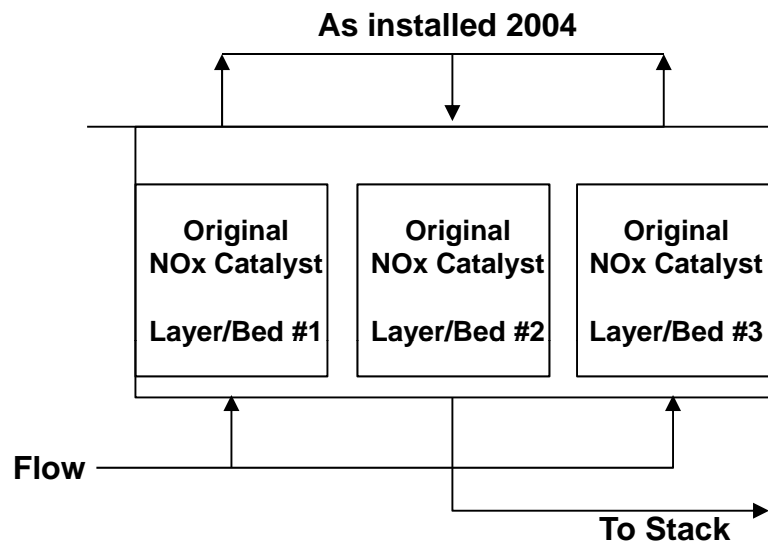
Project Summary



- **One of three layers not needed**
 - **Improvements in the catalyst formulations**
- **Improvements in catalyst conversion performance at lower temperatures.**
- **NOx reduced to 0.075 lb/MMBTU at 350 degrees Fahrenheit.**
- **NOx conversion begins at 330 degrees Fahrenheit**
 - **Optimal at temperatures 360 degrees Fahrenheit and higher.**
- **1/3 catalyst volume removed**
- **Much improved NOx emissions conversion**
- **50% of the cost of new catalyst**



Catalyst Removal and Installation



- Removed and replace with regenerated catalyst
- Layer/Bed #2:
 - Open for CO catalyst
 - Currently used as by-pass
 - Isolation of layers possible for testing



Questions

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